# Global Ocean Internal Wave Database

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## LONG-TERM GOALS

Our long-term goal is to develop a global database of ocean internal waves observed primarily from spacecraft. This database will be publicly accessible and can be used for various purposes including understanding the statistical properties of internal waves and upper ocean dynamics in any ocean area of interest.

## OBJECTIVES

Our objectives are to extract information on ocean internal waves from Space Shuttle photographs and satellite SAR, to construct a database containing the information for global oceans and to make the database publicly accessible via the Internet. We will demonstrate the use of the database by performing statistical analyses of internal wave features and dynamic analysis of their evolution under continental shelf boundary conditions.

## APPROACH

The global database of ocean internal waves has two major sections, one for Space Shuttle images and a separate section containing SAR imagery from ERS-1, 2, Radarsat, and other spacecraft. The images will be accompanied by interpretation maps and text describing oceanographic properties of the imaged features. The database includes a home page, offers a standard format and is accessible to Internet users.

## WORK COMPLETED

We searched NASA and our own Space Shuttle archives to extract 72 cases of ocean internal waves observed in various parts of the globe. A separate section of the database was set up for SAR images of internal waves, provided by John Apel, Antony Liu, and other investigators. Interpretation maps and text describing oceanographic properties of the imaged features have been prepared to accompany one third of the images. A demonstration study for using the data base has been performed, including statistical analysis of ocean internal wave features and dynamic analysis of the evolution of ocean internal waves under continental shelf boundary conditions.

## RESULTS

Based on the data contained in the database, one can conclude that ocean internal waves are common and can be observed by spaceborne SAR and visible imagery in all ocean regions, including the Atlantic, Pacific, Indian Oceans and major seas. In the open ocean their wavelengths have a Gaussian distribution, while closer to shore the distribution is skewed (Raleigh). Most of the internal waves were generated by the interaction of the semidiurnal tide with the edge of the continental shelf. Tests showed that all internal wave images and interpretation maps in the database can be downloaded and accessed via the Internet. Adding a SAR section has significantly expanded the database. Examples of a Space Shuttle image and a SAR image are shown in Figures 1 and 2, respectively.

## IMPACT/APPLICATION

When completed, this Internet-accessible database will represent the largest collection of internal wave imagery observed by spacecraft over most of the globe. The sample size will be large enough for scientists to evaluate the general statistical properties of internal waves in various parts of the oceans. Furthermore, it will be possible to test models and obtain detailed descriptions of internal waves at specific ocean sites.

## TRANSITIONS

A dozen scientists from several countries have already requested imagery from our internal wave database. Seven papers using the data from this database have been published (or submitted) in scientific journals and conferences.

## RELATED PROJECTS

1 – We are working closely with John Apel, who is analyzing SAR images of internal waves and providing input into our database (e.g. SAR imagery of strait of Gibraltar).

2 - Antony Liu at NASA/GSFC is analyzing internal wave data from the Pacific Ocean (e.g. South China Sea) and providing results to our database.

## PUBLICATIONS

Klemas, V., Q. Zheng, and X.-H. Yan, 2000. Space Station and Space Shuttle Studies of Ocean Dynamics and Coastal Resources. Proc. of Conf. on International Space Station Utilization. Albuquerque, NM, February 1-3, 2000.

Klemas, V., Q. Zheng, and X.-H. Yan, 2000. A Database of Ocean Internal Waves. Proc. 28th Int. Symp. On Remote Sensing of Environment. Capetown, South Africa, March 27-30, 2000.

Klemas, V., Q. Zheng, and X.-H. Yan, 2000. Space Shuttle Studies of Ocean Internal Waves. Proc. Sixth Int. Conf. on Remote Sensing for Marine and Coastal Environments, Charleston, SC, May 1-3, 2000.

Zheng, Q., X.-H. Yan, W. T. Liu, and V. Klemas, 2000. Estimating Ocean Surface Currents Using Space Shuttle Images of Oil Slicks. AGU 2000 Ocean Sciences Meeting, San Antonio, TX, January 24-26, 2000.

Zheng, Q., X.-H. Yan, W. T. Liu, and V. Klemas, 2000. Solitary Waves in the Atmosphere and Ocean Observed from Space, Overseas Chinese Ocean-Atmosphere Remote Sensing Workshop, Hong Kong, China, July 6-7, 2000.

Zheng, Q., V. Klemas, X.-H. Yan, and J. Pan, 2000. Nonlinear Evolution of Ocean Internal Solitons Propagating along an Inhomogeneous Thermocline, J. Geophys. Res., submitted.

Zheng, Q., X.-H. Yan, W. T. Liu, and V. Klemas, 2000. Space Shuttle Observations of Open Ocean Oil Slicks, Remote. Sensing of Environment, accepted.

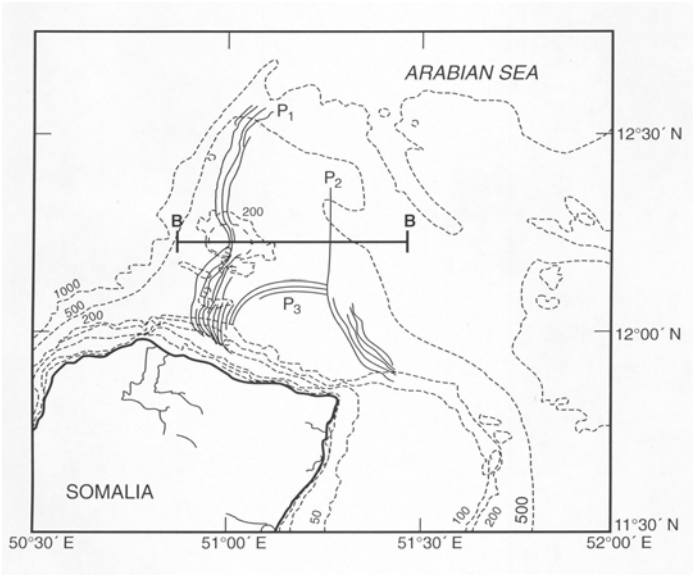


***Figure 1. Space shuttle image of internal waves off the coast of Somalia.***

There are three groups of long curved lines distributed in the central ocean area. The first group, $P_1$, crosses the ocean area from the south to the north along $51^0$E longitude. The curves in the group appear to be very bright due to extremely strong solar illumination on the ocean surface within the sun-glint in the tropical area. The second, $P_2$, is located to the east of group $P_1$, and the third group, $P_3$, is in-between, close to the coast and intersects with $P_2$. One can clearly interpret these groups of curved lines as representing three ocean internal wave packets. According to their curved directions, we interpret that groups $P_1$ and $P_2$ propagate westward and $P_3$ propagates northward (off shore). Group $P_2$ is a follower of $P_1$.

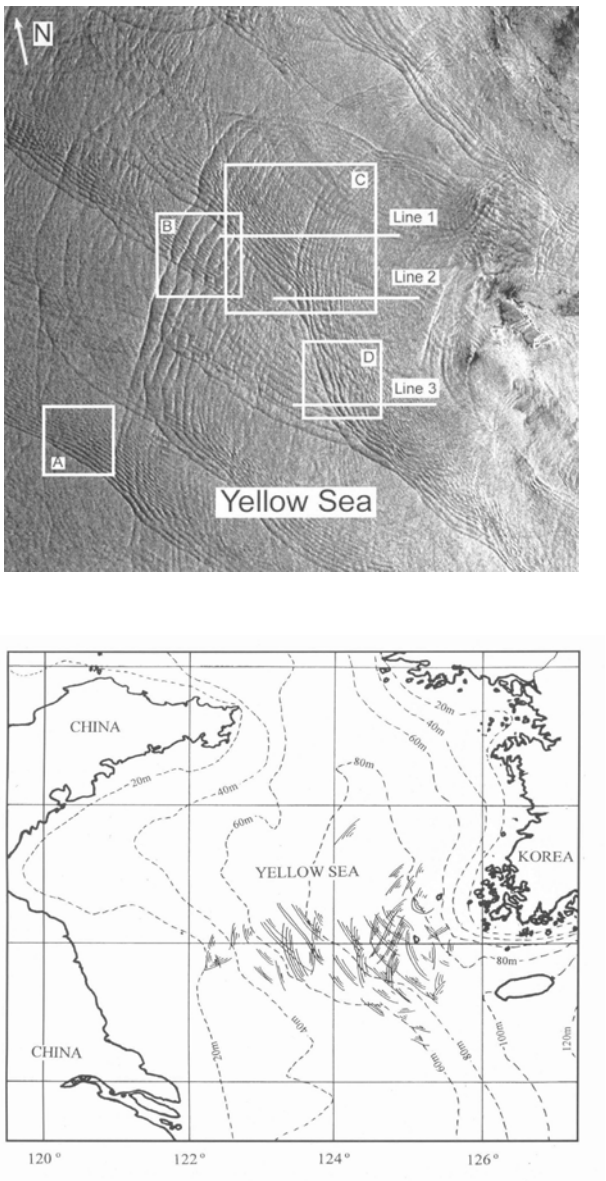


***Figure 2. ERS-2 Synthetic Aperture Radar (SAR) image of internal waves in the Yellow Sea.***

Several internal wave packets were generated from the island near the southwest tip of the Korean Peninsula by the collision of the Korea coastal current and the semi-diurnal tides. There are at least two generation sources (islands), one from the east and and the other from the northeast. Notice that the phase fronts of internal wave packets are shifted and distorted in the interaction areas due to the nonlinear wave-wave interaction. The windows A and B are considered as individual internal wave packets generated at an earlier time and without interaction. Window C shows the waves in the interaction zone, and window D shows the merger of wave packets after the interaction. shelf boundary conditions.